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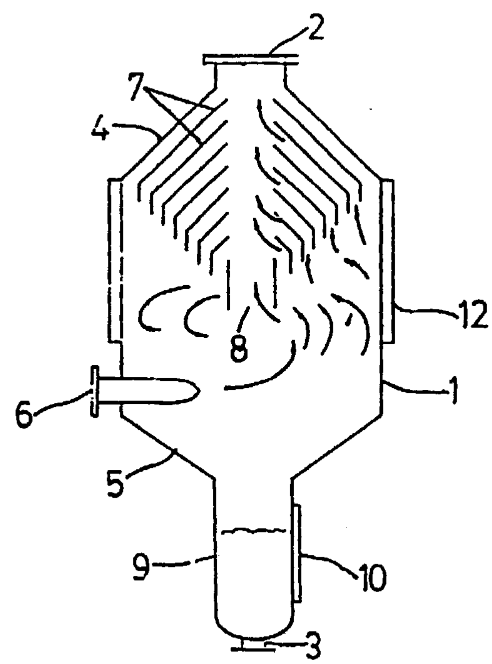
(54) Title: ENHANCED VACUUM CYCLONE

(57) Abstract

A cyclonic vacuum evaporator (1) comprising a chamber (5) having at least one entry port (6) and a plurality of conical elements (7). Introduction of a liquid mixture into the chamber (5) causes vapors to circulate towards the central part (8) of the chamber (5) and exit through the upper part (2) of the chamber (5) while liquid distillate collects in the lower part (9) of the chamber (5).

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## ENHANCED VACUUM CYCLONE

This invention describes a relatively simple and yet an essentially maintenance free vacuum cyclone evaporator fitted with internal parallel cones for enhancing of centrifugal force in the gas phase, the internal open cones provide an efficient liquid/vapor separation utilizing an internal fixed reflux effect.

Furthermore, this invention also claims the novelty of a distillation process as described, utilizing the vacuum cyclone evaporator together with the process design, it's features and how this can be used especially when refining of petroleum products.

The vacuum cyclone evaporator is especially useful in applications for distilling of heat sensitive or corrosive liquids but also in applications for crude oil or waste oil refining. Although various cyclones are used in the industry for the separation of liquids and solids, this invention partly relates to a specially designed vacuum cyclone evaporator, where liquids are separated by means of vaporization and the vaporized fraction is subsequently condensed. Due to the internal design, its efficiency is greatly enhanced, especially when used under severe vacuum conditions. Owing to the internal design, using a number of parallel open cones, an internal reflux effect is created, which in turn allows for the design of a simple and cost effective distillation/fractionator vessel for liquid separation.

## DESCRIPTION OF THE ENHANCED VACUUM CYCLONE

See Fig. 1 - The vessel body is essentially

designed as a vertical cylinder having one vapour outlet at the top and one outlet at the bottom for liquids. The top and bottom ends are either of dome or conical shape. One or two side mounted flanged nozzles are fitted which are easy to remove and maintain if necessary. These nozzles are designed to provide a tangential injection inside the vessel and thereby creating a swirling motion to the injected liquid and evaporated gasses.

The wall thickness of the vessel has been designed to withstand full vacuum and over pressure under high temperature. The height and diameter of the vessel is specially calculated to cater for a minimum of vacuum load inside the vessel during operation. For each type of liquid a separate calculation is required in order to decide appropriate dimensions for the vessel. Inside the cyclone, a number of open parallel cones of steel plate are installed. These open cones are fitted inside each other having an angle of say 30 deg. or more. The distance between each cone may be 50-100 mm.

One main feature of this invention is in fact the function of these parallel cones.

Industrial evaparation equipment is usually arranged for continuous operation with a large heat exchanger surface.

Boiling of the liquid or solution is often violent and there is usually a rapid vapour evolution. Evaporators in the industry therefore encounters many problems, such as foaming, scaling, corrosion and heat sensitivity.

A well known type of industrial evaporators is the so-called long tube vertical evaporator. These

are built as falling liquid film or rising liquid film evaporators. They often comprise a set of vertical heat-exchanger tubes to which liquid is fed and a liquid film is created on the exchanger tubes. The pressure drop through the tubes is usually very small, and the boiling liquid temperature is essentially the same as the vapour temperature. This type of evaporator is often used for concentrating heat sensitive materials such as fruit juices, because the hold-up or residence time is very small, the liquid is not overheated during the passage through the evaporator and heat transfer coefficients are high during low boiling temperatures.

Another type of evaporators are those so-called "thin film evaporators" which have successfully been used in the distillation of waste oils and other heat sensitive liquids. However, these evaporators are relatively expensive to build as well as maintain and operate, especially when high temperature and high vacuum is required for the operation.

Flash evaporators are known in which heat exchanger tubes are used to heat the liquid to above its boiling point and give a superheated liquid which is then flashed into a separator operating at a reduced pressure. Flash evaporators are often used as a component of a multistage evaporator process in for example the desalination of sea water. A disadvantage of a flash evaporator, however, is that the liquid throughout the system is at almost the discharge concentration which has limited its industrial use to solutions where no great concentration differences are required between feed and product.

An advantage of flash evaporators is however

that a relatively small number of pumps and associated equipment is required as well as no moving parts are required in the evaporators.

The present invention sets out to provide a method of evaporation having some of the characteristics of a flash evaporator and some of a cyclone vacuum evaporator.

Superheated liquid is tangentially injected into a cylindrical vessel under vacuum, where a proportion of the superheated liquid flash evaporates. Inside the vacuum vessel the liquid phase as well as the vapour phase is given a fast swirling motion.

At this point the two phases separate with the vapour phase moving up towards the conical parallel cones and the liquid phase moves down to the liquid deposit.

Although the injected superheated liquid velocity is relatively small (5-10 meters per second) calculations have indicated that the vapour phase which is flashed off may reach a velocity of the speed of sound (300 meters per second). This relatively high speed may better be explained when realizing that the vacuum in the cyclone is maintained at approximately 1% of that of an atmosphere (2-10 mbar. abs.). Thus the vapour mass and the friction inside the cyclone is very much reduced.

When three vapours rotate inside the cyclone at this relatively high velocity, heavier as well as small particles together with vapour droplets are separated and thrown towards the inside wall. At the center of the evaporator, clean vapours are drawn off up to the condenser which is fitted on top of the

evaporator. Rotating vapours inside the evaporator, which are moving upwards, but are not located at the center of the evaporator, are trapped in the internally arranged open cones. These cones now rapidly reduce the radius of the rotating vapours which also lose some of it's peripheral velocity. Heavier particles entrained in the vapour phase are forced towards the outer wall due to increased centrifugal force. These particles are forced to the inner side of the open cones where a flocculating effect occur. Small droplets also gather together onto these inner walls and form larger droplets which are drained off to the bottom of the vessel.

As the rotational velocity of the vapours decrease due to reduced diameter inside the open cones, also a small pressure increase will occur. This pressure increase (or vacuum loss) has the effect of condensing heavier molecules that have been evaporated.

This arrangement is especially useful when distilling or refining of mineral oils or even waste oils, as this has the effect of an internal reflux.

The lower the pressure (higher the vacuum) is, the more effective becomes the internal reflux.

The efficiency of liquid/vapour separation can often be demonstrated with the formula:

$$V = \sqrt{\frac{D(Pl - Pg)}{0{,}01164\, Pg}}$$

V is the velocity of settling. Pl is the density of liquid droplets. Pg is the density of vapour at vacuum condition D is a measure of size distribution of droplets to be separated.

The centrifugal force on a particle can be demonstrated with the following formula:

$$F_c = \frac{m \cdot v^2}{r}$$

Fc = Centrifugal force

m = mass

v2 = peripheral velocity

r = radius of the periphery (cyclone)

Thus the smaller the radius is the higher is the centrifugal force.

As an example: the centrifugal force in the vapour phase having a velocity of say 200 meters per sec. and rotating inside an evaporator with the diameter of 1 meter can reach 1000 g.

**THE APPLICATION OF AN ENHANCED VACUUM CYCLONE**

The following sets out to desribe the application of an enhanced vacuum cyclone when used as an evaporator for distilling of waste oils, such as waste engine oils and waste lubricating oils.

See Fig. 2 - Waste oil is injected at the inlet feed (1) where it passes through a horizontally mounted inlet bend or a tangential injection (2). A steady continuous flowrate is maintained to provide a stable operating condition and balance to the process system. When the liquid feed enters the evaporator at the inlet (2), a mixing takes place with circulated liquid with the non vaporized portion in the evaporator system. This circulated liquid is pumped by pump (8) via a specially designed heater or heat exchanger (5) before entering the evaporator. This circulated liquid is pumped at a flowrate preferably some ten times greater than the injected feed (1). The reasons for this higher flowrate is to maintain

low temperature differential over the heater and maintain a reduced coking effect in the tubes. This arrangement is often called forced recirculation. Howver, great care must be taken when distilling of waste oils, as the coking tendencies are known to be severe.

The heater (5) can be of a direct fired type using gas oil or natural gas. Generally the heater can be mounted horizontally or vertically as required due to burner design. Also heat exchangers can be used where the heating medium is suitable for heating at the required temperature levels.

As the inlet feed enters the evaporator as earlier described, a portion of the feed is evaporated. These vapours are drawn up to the internal parallel cones, where a partial reflux takes place and further to the condensers (7) and (8). The condensate is later collected in the receivers (6a and 6b).

The condenser (7) is of direct contact type using the cooled recirculated condensate from it's own circuit in the receiver (6a) as motive liquid. This motive liquid is circulated and cooled over the cooler (9).

The direct type condenser has the advantage that the recirculated cooling liquid can easily be maintained at any desired temperature, thereby also allowing a desired viscosity or fraction to be condensed in the first condenser.

The second condenser has the function of condensing any lighter fractions that has passed the first condenser. In this way two fractions can be drawn of from the distillation system.

Figure 3 schematically represents the process of the fractioned distillation by means of the evaporator 1. The conduit 11 facilitates entry of the liquid mixture into the chamber and the pump 13 produces a circulation of recovered liquid in the lower part 9 of the chamber towards the heat interchanger 14, with devolution of the liquid towards the conduit 11.

The vapors exit the chamber through 2. The chamber is connected to a sprinkler condenser 15 which liquifies a portion of those vapors. The liquid phase is removed through the lower conduit 16. This communicates with the deposit receiver 17, whose content consists of the distillates of the heaviest weight, which are sent to the exterior of the system by means of the pump 18.

The medium weight distillates are driven towards the cooler 19 and transported again, via conduit 20, towards the condenser 15 in spray form which mixes with the vapors present in the condenser, continuing the cycle in the interior of the device.

The exit 21 of the vapors from the upper part of the condenser 15 passes through condenser 22 connected to conduit 23, by which spray of air is made at a very high vacuum. The conduit 24 originates the derivation of the light distillates towards the deposit receiver 25 and its sending to the exterior by means of the pump 26.

The motor oils and the residual lubricant oils are typical products for treatment by means of the arrangement of Figure 3.

The conduit 11 acts as a horizontally mounted curve for the tangential injection through the small

entrance 6, producing a mix of injected liquids with the circulating material and with the non-vaporized part of the system. The recirculated liquid, driven through the pump 13 circulates at a velocity of the order of 10 times greater, approximately, than the velocity of the entrance of the conduit 11. Thus, it is maintained below the differential of temperature with respect to the heater 14 and a reduced effect of coking in the conduits, aspect that should be considered in the case of the residual oils.

The heater 14 can be fueled by means of gas oil or natural gas, can be mounted horizontally or vertically and can work with thermal changers when this type of operation is advisable.

The condenser 15, of the direct type, has the advantage that the recirculated liquid can be readily maintained at whatever convenient temperature is desired, permitting the product to have a desired viscosity or ensuring that the same condenses in the phase in question.

The condenser 22 condenses whatever light fraction might have passed through the condenser 7; in this manner two different fractions can be obtained in the installation.

## CLAIMS

1. A cyclonic vacuum evaporator for the separation of volatile components of different densities mixed with liquids, said evaporator comprising:

a chamber having at least an entry port in tangential disposition and horizontal with respect to internal walls of the chamber; and

a plurality of coaxial conical elements disposed within said chamber, said conical elements being equidistantly separated from each other and defining multiple intermediate conical spaces for the circulation of separated vapors and eventual condensation on surfaces of the conical elements of liquid portions of the mixture;

wherein vapors circulates towards the central part of the chamber and exit through the upper part of the chamber, while the lower part of the chamber forms a cylindrical collector for liquid distillates.

2. A cyclonic vacuum evaporator according to claim 1, wherein said conical elements have surfaces extending at an angle of at least about 30° to the horizontal.

3. A cyclonic vaccum evaporator according to claim 1, wherein the distance between each cone is about 50 to 100 mm.

4. A cyclonic evaporator according to claim 1, wherein said conical elements define a central upwardly extending vertical passage.

5. A cyclonic evaporator according to claim 1, wherein said at least one entry port is disposed

below a plane containing the lowest conical element.

6. A cyclonic evaporator according to claim 1, wherein a cylindrical guide tube is disposed in a lower region of said conical elements.

7. A cyclonic vacuum evaporator according to claim 1, and further comprising at least one external heating device.

8. A cyclonic vacuum evaporator according to claim 1, wherein an upper internal portion of said chamber is of conical shape.

9. A cyclonic vacuum evaporator according to claim 1, and further comprising a level indicator.

10. A cyclonic vacuum evaporator according to claim 1, and further comprising an exit port for discharge of the liquid part.

11. A cyclonic vacuum evaporator according to claim 1, and further comprising a condensor connected to an upper portion of said chamber.

12. A fractional distillation process comprising the steps of:

introducing a liquid mixture tangentially into a lower portion of a chamber of an evaporator as defined in claim 1 to cause a portion of the mixture to evaporate producing vapors which are drawn upwardly into contact with the conical elements; and

collecting condensed liquid in a lower portion of said chamber.

13. A process according to claim 12, wherein condensed liquid is recirculated by means of a pump through a heat interchange heater.

14. A process according to claim 12, wherein said liquid mixture is introduced at a velocity of about 5 to 10 meters per second.

15. A process according to claim 12, wherein said chamber is maintained under a vacuum of about 2 to 10 mbar abs.

16. A process according to claim 12, wherein the mixture is introduced to induce a swirling motion of liquids and vapors within said chamber.

FIG. 1

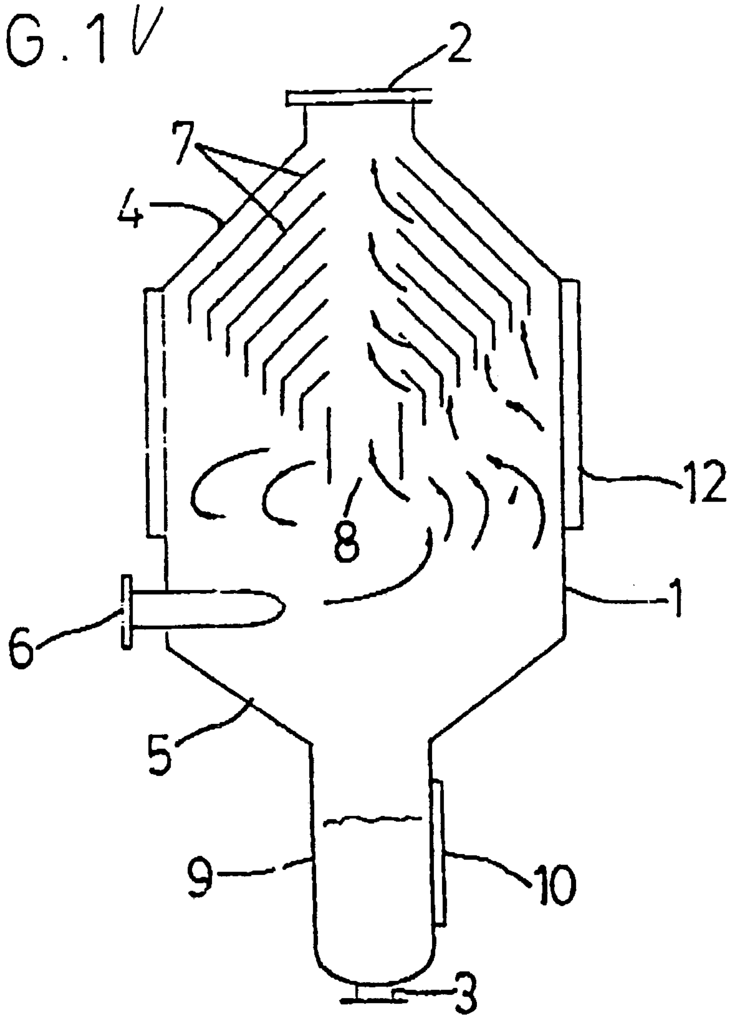
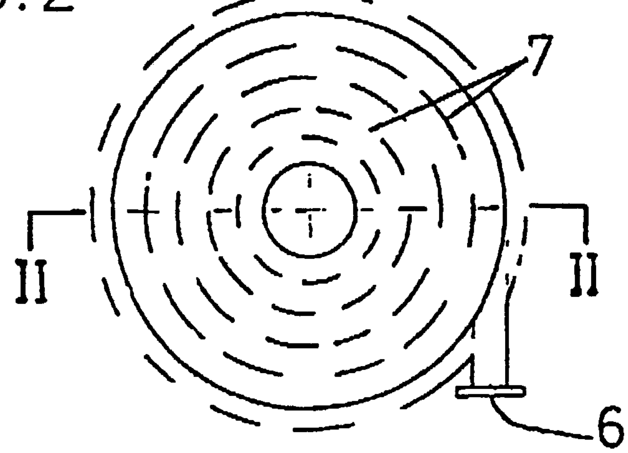



FIG. 2



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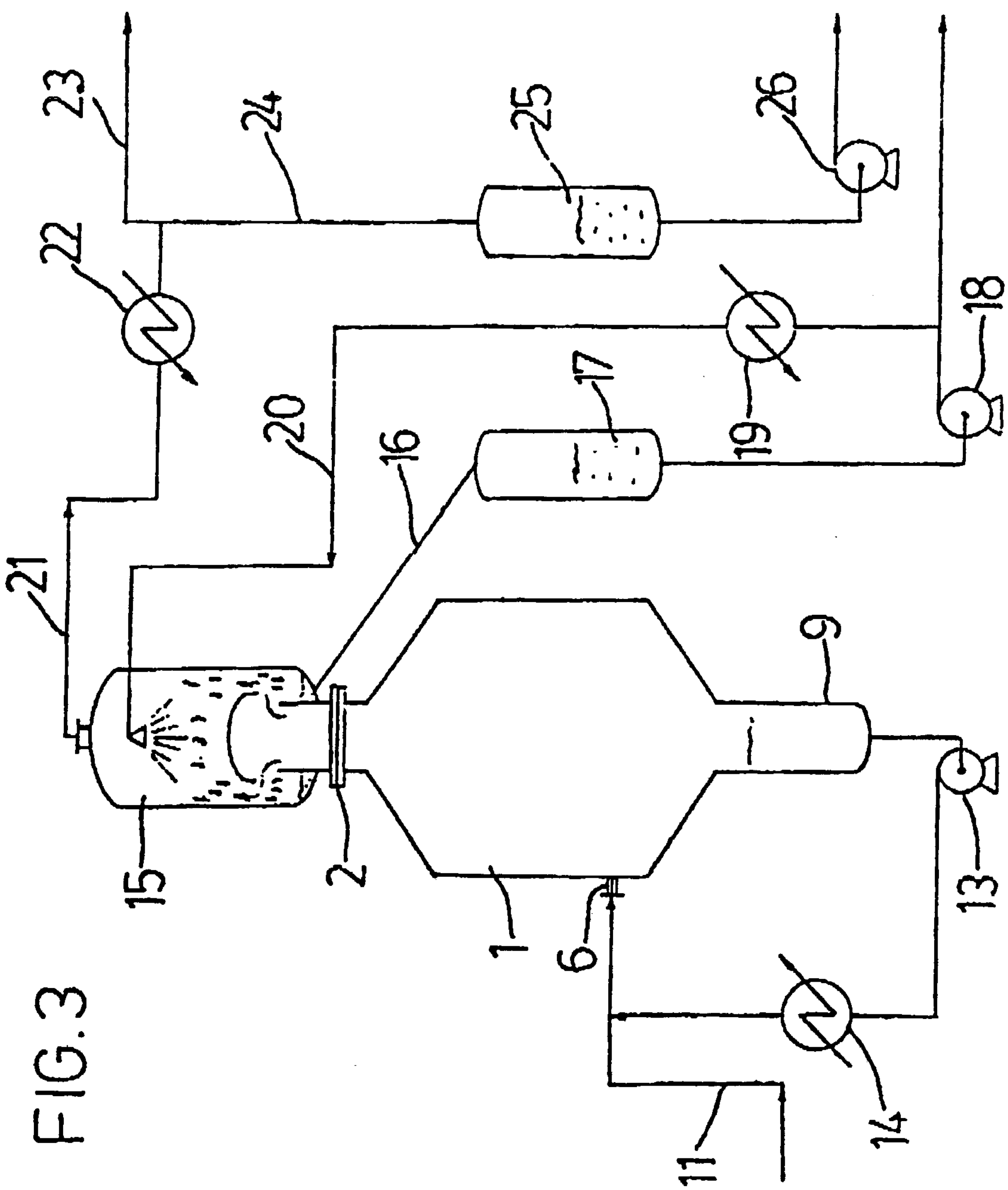


FIG.3

# INTERNATIONAL SEARCH REPORT

International Application No PCT/US90/02004

**I. CLASSIFICATION OF SUBJECT MATTER** (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC (5) : B01D 3/10,3/14,45/10

U.S. Cl : 55/444;202/197,198,205; 203/40

**II. FIELDS SEARCHED**

Minimum Documentation Searched [4]

| Classification System | Classification Symbols |
|---|---|
| U.S. | 55/444; 122/489,492; 159/23,DIG.16; 196/136; 202/153, 161,181,185.1,197,198,205,235; 203/1,40,87,94,98 |

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

**III. DOCUMENTS CONSIDERED TO BE RELEVANT** [14]

| Category * | Citation of Document, [16] with indication, where appropriate, of the relevant passages [17] | Relevant to Claim No. [18] |
|---|---|---|
| Y | GB,A 528,145 (AKTIEBOLAGET SEPARATOR) See page 2, lines 34-59. 23 October 1940 | 1,2,4,5,8, 10 & 11 |
| Y | US,A 4,375,386 (WINDHAM) 01 March 1983 See figure 6, column 4, lines 64-68 and column 5, lines 1-20 and lines 30-39. | 1,5,7,10-13, 15 & 16 |
| Y | US,A 4,417,951 (STANISIC ET AL) 29 November 1983 See figures 1 & 6. | 1 & 4 |
| A | US,A 1,689,745 (NICHOLS) 30 October 1928 See figure 3. | 1 |
| A | US,A 2,201,961 (STOLTZ) 21 May 1940 See figures 1 & 6. | 1 & 4 |
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**IV. CERTIFICATION**

| Date of the Actual Completion of the International Search [2] | Date of Mailing of this International Search Report [2] |
|---|---|
| 04 SEPTEMBER 1990 | 19 NOV 1990 |
| **International Searching Authority** [1] | **Signature of Authorized Officer** NGUYEN NGOC-HO INTERNATIONAL DIVISION |
| ISA/US | for WILBUR L. BASCOMB, JR. Ngoc-Ho Nguyen |

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III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

| Category * | Citation of Document, [16] with indication, where appropriate, of the relevant passages [17] | Relevant to Claim No [18] |
|---|---|---|
| A | US,A 2,368,049 (STRATFORD) 23 January 1945 See figure 1. | 7 & 9 |
| A | US,A 4,308,105 (SCHIFFERS ET AL) 29 December 1981 See figures 1 & 2. | 13 |
| A | US,A 4,818,346 (BENTHAM ET AL) 04 April 1989 See figure 3. | 1 & 12 |